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The Telecommunications Emergency Decision Support System as a crisis management decision support system

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THESIS

THE TELECOMMUNICATIONS EMERGENCY
DECISION SUPPORT SYSTEM AS A CRISIS
MANAGEMENT DECISION SUPPORT SYSTEM

by

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The Telecommunications Emergency Decision Support System (TEDSS) is an automated management tool to aid the government in the management of the nation's telecommunications resources during a national emergency. The current version of TEDSS uses conventional database technology which is rapidly becoming inadequate to entice the "computer naive" manager to use the system under pressure. The National Communication's System which oversees TEDSS is interested in opportunities to incorporate emerging technologies into its program. The purpose of this thesis is to consider TEDSS in the context of Crisis Management Decision Support Systems (CMDSS) in order to determine generic requirements for a CMDSS, survey the technology current implementations, and assess the potential for applying this technology to a revision of TEDSS. A further objective is to survey emerging technologies not found in CMDSS which can be transferred to TEDSS. The result of the research indicates that technology found in CMDSS is not much more advanced than TEDSS. Emerging technologies which would enhance crisis decision making support for TEDSS include geographical information systems, graphical user interfaces, optical storage and voice recognition.

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The Telecommunications Emergency Decision Support System as a Crisis Management Decision Support System

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ABSTRACT

The Telecommunications Emergency Decision Support System (TEDSS) is an automated management tool to aid the government in the management of the nation's telecommunications resources during a national emergency. The current version of TEDSS uses conventional database technology which is rapidly becoming inadequate to entice the "computer naive" manager to use the system under pressure. The National Communication's System which oversees TEDSS is interested in opportunities to incorporate emerging technologies into its program. The purpose of this thesis is to consider TEDSS in the context of Crisis Management Decision Support Systems (CMDSS) in order to determine generic requirements for a CMDSS, survey the technology current implementations, and assess the potential for applying this technology to a revision of TEDSS. A further objective is to survey emerging technologies not found in CMDSS which can be transferred to TEDSS. The result of the research indicates that technology found in CMDSS is not much more advanced than TEDSS. Emerging technologies which would enhance crisis decision making support for TEDSS include geographical information systems, graphical user interfaces, optical storage and voice recognition.

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I. INTRODUCTION

A. BACKGROUND

Effective management of essential telecommunications resources in time of national crisis is critical in ensuring that the federal government fulfills its responsibility for the survival and welfare of its people. The National Communications System (NCS) is an organization created to provide necessary communications for the federal government under all conditions ranging from normal situations to national emergencies.

The Telecommunications Emergency Decision Support System (TEDSS) is an automated management tool to aid the government in the management of the nation's telecommunications resources during national emergencies. TEDSS provides interactive information processing and decision support to the manager, NCS, the NCS regional communications managers, the NCS relocation sites, the NCS emergency preparedness operations personnel, and the national communications coordinator (NCC).

B. PROBLEM

The current version of the TEDSS uses conventional database technology which is rapidly becoming inadequate to entice the "computer naive" manager to use the system under pressure. TEDSS runs on Digital Equipment

Corporation (DEC) MicroVAX Computers using the Virtual Memory System (VMS) operating system. It was developed with the INGRES relational database management system and the C programming language.

A relational Database Management System (DBMS) can be better employed as a building block rather then as the foundation of TEDSS. A System with a DBMS fourth generation language (4GL) is too restrictive for the flexible graphics functionality that emerging technology can provide for TEDSS.

Emerging technologies which have superseded the database technology underlying TEDSS include optical disk, hypertext, voice recognition, window-based graphical user interface (GUI) and geographical information systems (GIS). Optical disks have much higher recording densities than conventional magnetic disks. Optical disks were originally developed for recording television programs but because of their large capacity, can be used for storing map data. Hypertext is a mechanism which allows direct machine-supported references from one textual chunk to another. User interfaces provide the user with the ability to interact directly with these chunks and to establish new relationships between them. Using hypertext, windows on a screen can be associated with objects in a database, and links are provided between these objects, both graphically and in the database. Voice recognition is the ability of a computer system to recognize spoken words from a given vocabulary. Voice recognition can become a force multiplier in situations where users may be too occupied

to attend to conventional user interface activities. Windows-based GUI systems can easily replace menu driven systems as the underlying system interface. Window-based GUI systems provide a consistent dialog box interface which makes systems easier and more attractive to use. GIS is the common term for systems associated with electronic mapping. With GIS, TEDSS resource information can be presented using detailed mapping techniques which can enhance the meaningfulness of information presentation.

The field of information technology has undergone sustained and spectacular growth in term of reduced cost and increased performance. These improvements continually give rise to new families of applications as well as permitting old applications to be done in novel ways. The NCS is interested in opportunities to incorporate emerging technologies into its program to enhance the survivability and endurance of the National telecommunications infrastructure.

C. SCOPE OF THESIS

Crisis management information systems (CMIS) are decision support systems (DSS) specifically designed for supporting crisis decision making. Crisis decision making is usually characterized as decision making under conditions of extreme stress, short decision time and high threat (Eom and Lee, 1990, p. 1). DSS which deal with crisis management are slowly emerging as a special area of interest.

The main thrust of this thesis is to conduct a literature search of crisis management information systems in order to survey the technology they employ and assess the potential for applying this technology to the TEDSS. A further objective is to survey emerging technologies such as voice recognition, optical disks, and hypertext for possible inclusion in crisis management decision support systems (CMDSS). The major research questions are as follows:

- What are the major characteristics of a CMDSS?
- What is the inventory of the technology found in existing crisis management information systems?
- Which of these technologies are transferrable to a revision of TEDSS?
- What other technological alternatives would enhance the TEDSS?

This research will be limited to the analysis of TEDSS and other similar CMDSS. The results of this research can be used to facilitate the design of a new version of TEDSS which incorporates current technology.

D. LIMITATIONS

A major limitation of this research is the small population of existing documented crisis management information system available for analysis. In industry and governmental organizations, there are many formal, computer-based systems for retrieving data to provide information for managerial

decision making. Crisis management is an emerging field in DSS and, as such, the literature on the subject is scant.

E. METHODOLOGY

The research methodology used for this thesis consists of performing a literature survey of crisis management decision support systems, developing a framework for CMDSS in the form of desirable requirements for such a system, examining four systems including TEDSS and classifying the technology which they use, and analyzing the potential for technology transfer to TEDSS.

F. STRUCTURE OF THE THESIS

The contents of the remaining chapters of this thesis consist of the following:

- Chapter II discusses a framework for CMDSS. In establishing this framework, elements of crisis decision making and characteristics of a CMDSS are identified.
- Chapter III provides an analysis of TEDSS and four other CMDSS found in the literature survey with respect to the parameters identified in Chapter II.
- Chapter IV discusses the use of new technology which can be deployed for CMDSS, particularly in the TEDSS environment.
- Chapter V summarizes how TEDSS can be improved by considering it in the context of CMDSS. The research is summarized and recommendations are made. In addition, this chapter provides related topics for future research.

II. FRAMEWORK FOR CRISIS MANAGEMENT DECISION SUPPORT SYSTEMS

A. NATURE OF CRISES

New ground must be broken to set criteria by which crises can be identified and classified. Presently, there are differing schools of thought on what comprises a crisis. C.F. Hermann offers the following definition:

> ...a situation is said to be crisis if, and only if, (1) threatens one or more important goals...(2) allows only a short time for decision before the situation is significantly transformed, and (3) occurs as a surprise to the decision maker. (Hermann, 1972, p. 6)

Hermann's definition of crisis fails to recognize other important characteristics which are embedded in crisis decision making.

Billings, Milburn, and Schaalman work in the area of characteristics of a crisis lean toward the idea that crisis is a matter of a decision maker's perception. They contend that perceived value of possible loss, perceived probability of loss and perceived time pressure dictate the extent of perceived crisis. Each of the three principal inputs has other underlying variables which lead to the principal inputs. For example, perceived value of possible loss is derived from the problem sensed and perceived importance of the problem area. Confidence in the accuracy of a desired state, indicators of the existing state, alternative explanations for the apparent discrepancy between the two, and response uncertainty affect the perceived probability of loss. Perceived

time pressure depends upon the perceived negative consequences if a problem is disregarded and the perceived time to search for satisfactory solution. (Billings, *et al,* 1980)

B. CRISIS DECISION MAKING

Crisis decision making is characterized as decision making under conditions which require a short decision time and involve high threat (Elam and Isett, 1987, p. 1). One of the direct effects of crisis decision making environment is stress. If a decision maker can control stress, he can often improve the quality of decision making. In crisis decision making, decision makers may rely on certain cognitive crutches that bring about less than efficient and totally effective decision making. The difference between a decision maker who can simply survive a crisis and one who is capable of turning the crisis into an opportunity may hinge upon a CMDSS.

Crisis decision making is a relatively new area for information system (IS) and has few research precedents. Elam and Isett identify three academic areas involved in crisis decision making research: management, psychology, and information systems. Management provides a foundation for understanding decision making; psychology is concerned with individual performance under stress and uncertainty; and information systems involve the use of computerized decision aids to increase the effectiveness of decision

making (Elam and Isett, 1987, p. 2). Figure 1 shows the conceptual integration of these areas as they pertain to crisis management.

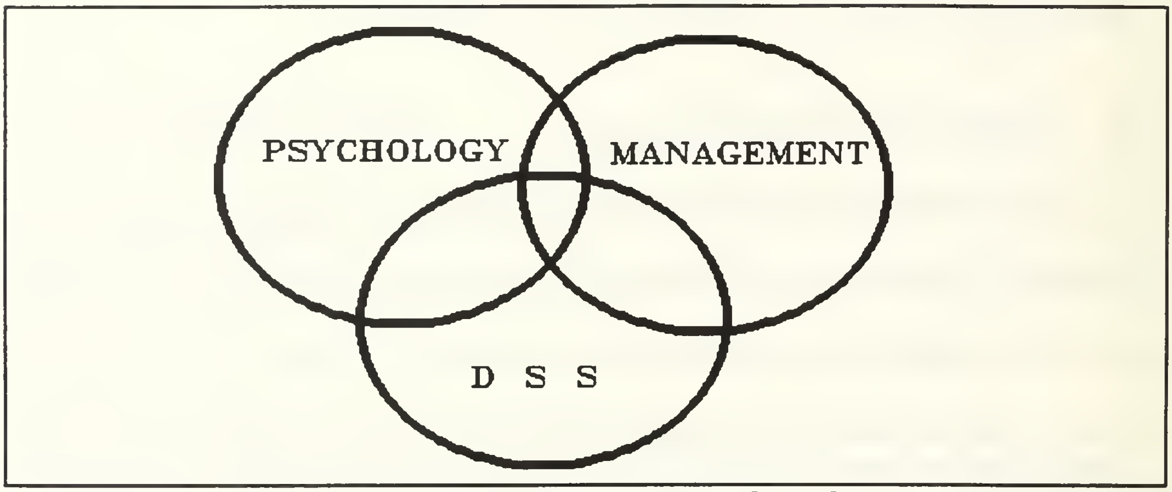

Figure 1. Research References Disciples for Crisis Decision Making

Management science involves a systematic approach to decision making. In this context, a decision is the conclusion of a process by which a decision maker chooses between two or more available alternative courses of action for the purpose of attaining a goal (Turban and Meredith, 1981, p. 15). Decision making is part of the overall process of management. Turban and Meredith illustrate this by examining the managerial function of planning. They contend that planning involves a series of decisions such as "What should be done? When? Where? By whom?" which presupposes decision making.

Psychology in individual performance under stress and uncertainty is an area which is very relevant to crisis management. Some people react to stress differently than others. The danger in a crisis can be perceived as a threat to

any combination of the following: psychological safety, position within an organization, status, individuality, or survival (Fink, 1986, p. 133). However, the stress which accompanies crisis situations can also be shifted to useful and rewarding performance. For example, the American pilots who participated in the initial attack on Iraq were operating under extremely stressful conditions. They took the opportunity to channel that stress into a mode of vigilance which was ideal for conducting surgical strikes.

Computerized decision aids have been used as devices to support managerial decision making for over 20 years. Transaction processing systems (TPS), management information systems (MIS), decision support systems (DSS), expert systems (ES), and executive information systems (EIS) are all examples of computerized decision aids which are now called computer-based information systems (CBIS). In the context of this thesis, MIS and DSS are the decision aids which are most relevant. Keen and Scott-Morton's characteristics of a MIS and a DSS are summarized below.

- MIS main focus is on structured tasks where standards, rules and information flow are well defined.
- MIS are most effective in the role of improving efficiency and by replacing personnel.
- MIS relevance for manager's decision making is indirect; for example, by providing reports and access to data.
- DSS focus is on decisions which have enough structure for computer aids to support manager's judgements.

- DSS value is in extending the capability of managers' decision process to help them improve their effectiveness.

Of the three disciplines which encompass CMDSS, decision support is the most relevant to this thesis. Though there are few research precedents which deal specifically with DSS as a crisis management tool, work by Belardo *et al.*, has demonstrated that DSS can improve effectiveness and reduce stress in decision making (Belardo and Kirk, 1984). In this context, the TEDSS can be viewed as a CMDSS. Specifically, we want to look at the TEDSS requirements in the light of CMDSS and determine what technology is appropriate to meet those requirements. With this context in which to consider the TEDSS, a more realistic design based on current technology can be developed to fulfill the mission of NCS.

C. SPECTRUM OF DSS

A crisis management information system is a DSS specifically designed for supporting crisis decision making. Distinguishing between crisis and non-crisis management information systems can be a tricky endeavor. A literature survey of DSS revealed that there are very few DSS designed for crisis management actively in use today.

The concept of DSS was first articulated in 1971 by Scott Morton. Since then, the field has grown to encompass many areas suitable for DSS applications. Morton defines DSS as "interactive computer-based systems

which help decision makers utilize data and models to solve unstructured problems" (Morton, 1971). Additionally, Keen and Morton offer the following definition of DSS:

> Decision support systems couple the intellectual resources of individuals with the capabilities of the computer to improve the quality of decision makers who deal with semi-structured problems. (Keen and Morton, 1978)

Four major characteristics of DSS are as follows:

- DSS incorporate both data and models.
- They are designed to assist managers in their decision process in semistructured (or unstructured) tasks.
- They support, rather than replace, a manager's judgment.
- Their objective is to improve the effectiveness of decisions, not the efficiency with which decisions are being made. (Turban, 1990, p. 9)

A DSS model is streamlined portrayal of reality. A real-world situation is often too hard and complex to depict; therefore, models are simplified versions of the real world. Model are critically important because they transform data into information that is useful for decision making. An example of this is the damage assessment model in the TEDSS which provides predictions of resource damage from hypothetical nuclear detonation. These predictions allow the emergency manager to decide which telecommunications resources may still be operable.

Another key aspect of a DSS is that it is best suited for unstructured situations. Unstructured tasks refer to unclear yet intricate problems for which there are no distinct algorithmic solutions. Unstructured tasks require a blend of human judgment and computer analysis to filter information and identify viable alternatives. The damage assessment model again is a perfect example of an unstructured task which requires a model to provide relevant decision making information.

D. CLASSIFICATIONS OF DSS

A 1984 survey identified primary types of decisions made using a DSS as follows (Meadow and Keen, 1984, p. 119):

- General long-range planning
- Strategic assessment
- Product strategy
- Negotiation of budgets
- Reporting and analysis
- Operating planning and control
- Acquisition strategy
- Capital investment strategy
- Financial Strategy
- General budgeting
- Cash flow management

CMDSS would appear to fit in more than one of the above types of DSS, specifically, strategic assessment, and reporting and analysis. Strategic assessment normally deals with the effective conduct of a plan or action which is clearly central to crisis decision making (e.g., damage assessment, resource allocation, emergency response). Reporting and analysis is a task which is implied in most CMDSS. Information generated by CMDSS can be collected for reports. The analysis task is a product of understanding and filtering data which is often accomplished through the use of models.

A more recent survey of DSS applications devised a classification scheme consisting of nine categories of DSS applications as shown in Table I(Eom and Lee, 1990). They relied upon Sprague's definition of a DSS as a computer-based information system that "allows a specific decision maker or group of decision makers to deal with a specific set of related problems" (Sprague, 1980).

Under the Miscellaneous classification, their survey cited four articles about Emergency Response Systems, one article about Crisis Decision, one article on Pre-decision Planning, and three articles on Multiple Criteria Decision Making. No separate classification for CMDSS seems to exist yet. The most likely reason for this is that the field is still in its infancy; and no boundaries have yet been recognized.

TABLE I. CLASSIFICATION BY APPLICATION AREA

1. Corporate Functional Management [133 of 203]
2. Agriculture [3 of 203]
3. Education [7 of 203]
4. Government [6 of 203]
5. Hospital and Health-Care [10 of 203]
6. Military [7 of 203]
7. Natural Resources [12 of 203]
8. Urban and Community Planning [6 of 203]
9. Miscellaneous [19 of 203]

E. CMDSS CHARACTERISTICS

The basic requirements of a CMDSS can originate with the Sprague and Carlson DSS architecture of data, models, and dialog. For a CMDSS, this architecture can be enhanced to include knowledge which leads the CMDSS into the area of expert systems (Figure 2).

The data component of this architecture includes databases which reflect specific data requirements for the application, and the accompanying database management software. A DSS needs data to facilitate the building of various files and applications. ORACLE, INGRES, dBase IV, and R Base 5000 are examples of database management software which can support the data aspect of DSS architecture.

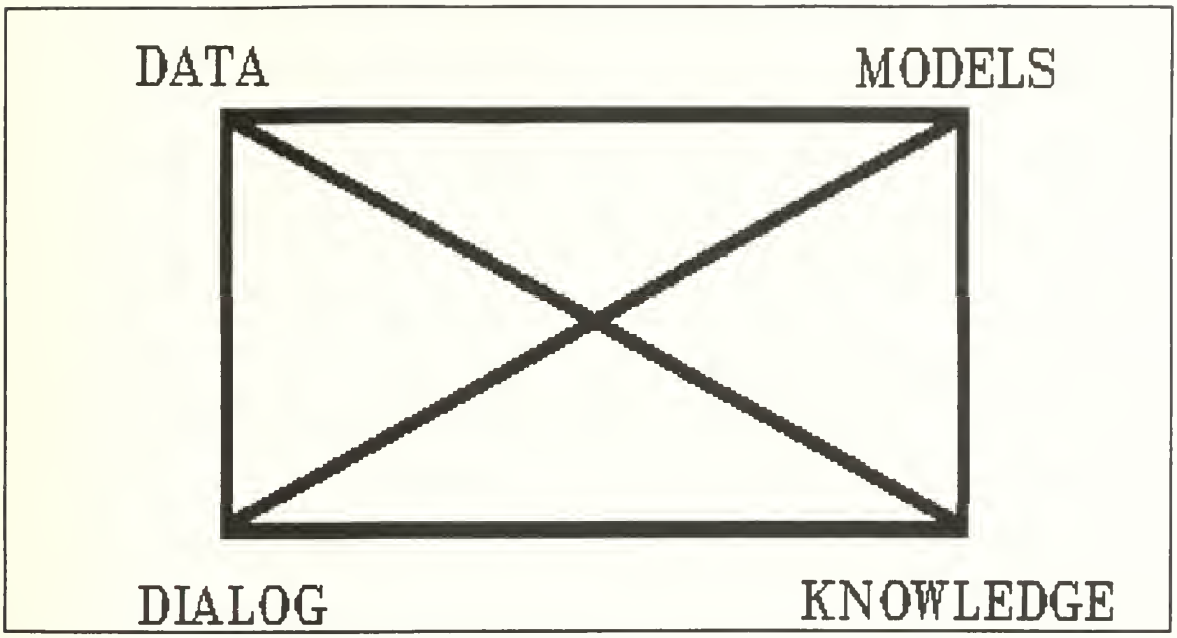

Figure 2. Components of a CMDSS

Model management includes software packages such as statistical, management science or other quantitative models that provide the system's analytical capabilities. A model base management system (MBMS) is a software system which facilitates model creation; model updating; model and data integration; data manipulation; and generation of new routines and reports. (Turban, 1990, p. 121)

User interface (dialog) is the subsystem through which the user communicates with the DSS. There are two aspects of a DSS interface: the command interface through which the user "tells" the DSS what to do, and the presentation interface through which the DSS presents the results of what it has done. The dialog is critical to the DSS because its flexibility and ease-of-

use can be the determining factor in whether a manager will use the system at all. An annoying user interface could cause a manager not to use the DSS to the maximum extent that the system allows or not at all.

Two of the interface styles that are of interest to this study are Command Language and Object Manipulation. Command Language allows the user to enter a command such as "Go" or "Quit". Some commands can be executed with function keys on the keyboard. Object manipulation is usually represented as icons or symbols that can be directly manipulated by the user. For example, the user can use the mouse or cursor to point at an icon, then use a command to move it, enlarge it, or show the details behind the object. (Turban, 1990, pp. 647-648)

The information presentation interface is important to users of CMDSS. Users react positively or negatively to the manner in which information is organized for presentation. The way the area of a display is structured, as well as the special methods of highlighting and signaling, can enhance or detract from the readability of display information.

Recent developmments in interface technology include the graphical interface (GUI), and dashboards for geographic information system (GIS) applications. An on screen dashboard contains objects as well as icon buttons and menu choices that are used to operate a GIS.

When a DSS incorporates knowledge, it moves within the boundaries of an expert system. The basic components of an expert system are the user, user-interface, explanation facility, knowledge update facility, knowledge base, and inference engine. A knowledge base is a database of facts often expressed as "IF-THEN" rules and an inference engine is a procedure which simulates human reasoning by operating on these rules. Knowledge is a desirable characteristic of a CMDSS as discussed below.

Elam and Isett generated a set of characteristics for a CMDSS which was culled from the work of Belardo, Wallace, Billings, *et al.*, Smart and Vertinksy. Theses CMDSS characteristics are as follows (Elam and Isett, 1987, pp. 6-7):

- Model of Crisis Environment - The CMDSS needs an understanding of the environment in which the decision is taking place.

- Rapid Response - The CMDSS must have a response time which allows the decision maker time to react to the unfolding situation. Unacceptable delay could negate the usefulness of even the most sophisticated system.

- Expertise - This is the most important aspect of the CMDSS and at the same time, the most difficult to achieve. Not only must it have the necessary models to represent the crisis but it must understand how to employ them and interpret what the results mean.

- Recommendation Facility - The CMDSS must be able to suggest courses of action so that the decision maker is relieved of otherwise complex analysis.

- Explanation Facility - In order to develop confidence and trust in the CMDSS, the decision maker will expect the system to be able to explain its recommendations and suggestions.

- Reliability - The CMDSS must function consistently and accurately with available information. Most importantly, it must notify the decision

maker when it is forced to work with less than reliable intelligence data and models (old, time-sensitive intelligence data, for example).

- Simulation Facility - As part of the interaction between decision maker and CMDSS, the CMDSS must be able to simulate not only its own recommended courses of action, but also to simulate actions being considered by the answer to "Why NOT?" questions.

- Multiple Expert Sources - The CMDSS must be built using the inputs of more than one expert in the field to avoid decision biases and limited experience.

- Ease of Use - If the CMDSS is to be used at all, it must have an interface which allows the decision maker faced with a crisis to develop his response options. Since the crisis decision maker cannot be concerned with the mechanics of using a computer, a voice interface would be appropriate, probably through a chauffeured access.

- Feedback - The CMDSS should be able to obtain feedback on the results of previous decisions and be able to incorporate these results in its models and its understanding of the crisis environment. Equally important, it should recognize when feedback is delayed, and when it is inconsistent with known facts so that the decision maker may learn as well.

- Information Compression - The CMDSS should filter and condense the otherwise tremendous amount of data which normally overloads the decision maker during crisis. This filtering is a function of the expertise and understanding of the system.

An investigation of system design consideration for emergency management decision support by Salvatore Belardo *et al.*, supports the notion that crisis decision making can be enhanced by DSS. Simulation tests were conducted to evaluate DSS design factors in the context of emergency management decision making. The simulation was conducted by the Federal Emergency Management Agency (FEMA) training facility located in Emmitsburg, Maryland. The exercise concerned the response to a nuclear

generating facility accident. The result of the experiment indicated clear support for computerization of emergency management decision support systems, and an apparent need to focus attention on further development of theses systems to improve the decision making capabilities of public managers during the later less structured stages of an emergency. (Belardo *et al.,* 1984, p. 795)

CMDSS requirements which surfaced from Belardo's experiment include:

- To improve effectiveness, CMDSS designed to assist emergency managers should prompt the manager with regard to critical activities (e.g., in notifying the appropriate personnel, etc.).
- CMDSS must not "overload" decision makers with unnecessary or confusing information.
- Knowledge should be built into the CMDSS to enhance expertise. As a result, the computerized CMDSS should help to increase the capability of the group as a whole as well as its individual members.
- Sophisticated graphics capabilities separate from the rest of the system also appear to be warranted. A graphics system which provides various pictorial capabilities such as cloud dispersion (current information, time sequence, etc.) would be vital in making correct assessments, particularly as the emergency grows and the situation deteriorates.

In establishing requirements for a CMDSS, one issue to be determined is whether a system should be responsive or directive. Responsive systems react only to users' requests whereas directive systems inform the decision maker of thoughts and recommendations which it has generated without user query. The determining factor as to whether a system is responsive or directive is the

level of interaction between the user and the system. For example, the current version of TEDSS is unable to take independent action without the express direction of the user; thus, TEDSS is a responsive DSS. The potential for launching a revised version of TEDSS into some level of directive DSS exists; however, care should be taken to not overload TEDSS with too many unnecessary requirements.

A key characteristic of crisis situations is "information overload" or "information compression" as Elam and Isett call it. Information overload is a bombardment of information from various sources such as sensors and human conversation. CMDSS such as TEDSS should be intelligent enough to interpret information regardless of its format, and filter information according to relevant critical success factors for use in reaching decisions. Information overload can be frustrating and wasteful and is not desirable in a system.

For the purpose of classifying a CMDSS, criteria must be developed which cover systems as diverse as TEDSS, which is designed to support national emergencies, and Southern California Edison's Information System for Crisis Management, which is designed to help prevent organizational crises from becoming disasters. The latter system is an integrated voice-data video information system developed for top managers to help prevent and control problems that might arise with their nuclear power generating station at San Onofre, California.

This is an example of a system for business crisis which in this case of nuclear power generation could conceivably become a national crisis. Business crises have been broadly defined as turning points in which impending danger to an organization runs the risk of escalating in intensity, interfering with normal operations of the business, jeopardizing the organization's public image, and damaging the organization's bottom line (Housel and Omar, 1986, p. 369).

F. FRAMEWORK FOR CMDSS

The vital features which would be important in the design of a CMDSS for emergency management are as follows:

- Rapid Response - A CMDSS should possess a response time which allows the user time to react to the unfolding situation.

- Reliability - A CMDSS must function with desired accuracy and dependability at all time. It must prompt the user when the system is forced to work with less than reliable intelligence data and models.

- Ease Of Use - A CMDSS should have an interface which allows the user faced with a crisis to develop his response options. For ease of use, the user can employ a voice recognition, or a window-based graphical user interface (GUI).

- Critical Activities Prompt - To improve effectiveness, a CMDSS designed to assist emergency managers should also prompt the manager with regard to critical activities.

- Information Overload - A CMDSS must be design to not "overload" decision makers with unnecessary or confusing information.

- Knowledge - Knowledge should be build into a CMDSS to enhance expertise where appropriate. As a result of knowledge, a CMDSS should help to increase the capability of the group as a whole as well as its individual members.

- Sophisticated Graphics - Sophisticated graphics capabilities separate from the rest of the system should be used to enhance efficiency. A graphics system which provides various pictorial capabilities of regions at the state, regional, and local level is recommended. This would help make correct assessments as the emergency grows and the situation deteriorates.

- Responsive System - Responsive systems react only to users' requests. User requirements should be investigated to ensure that a directive system is not needed.

- Real-Time System - A CMDSS should be a real-time system which requires timely response (1 to 120 minutes time range) to conditions which threaten cherished social values.

- Threat Conditions - CMDSS should be able to handle threat conditions which can consist of but not limited to the following:

    - Conventional Bombs or Fires
    - Floods
    - Terrorist Incidents
    - Tornadoes
    - Widespread Rioting
    - Hurricanes
    - Blizzards
    - Earthquakes
    - Oil Cutoffs
    - War (all types)
    - Reconstitution
    - Technological Crisis
    - Confrontational Crisis
    - Malevolence Crisis
    - Management Failure Crisis

Now that a framework for CMDSS has been presented, the next chapter will focus on four implemented CMDSS within the context of this framework which have been described in the literature. Additionally, the TEDSS will be analyzed within this framework.

III. EVALUATION OF SELECTED CMDSS IMPLEMENTATIONS

A. BACKGROUND

Through a literature survey of crisis management information systems, four CMDSS in addition to TEDSS have been identified for analysis. The capabilities and technology provided by each system are analyzed within the framework established in Chapter II to ascertain the potential usefulness of their technology to a revision of TEDSS. TEDSS is also analyzed.

Before launching into the four systems, a structure for facilitating the assessment of the technology in each of the CMDSS must be devised. The technology areas for evaluating the CMDSS are as follows:

- <u>Data</u> - The data management dimension includes the specific data requirements for the application and associated data management software.
- <u>Model</u> - The model management dimension includes a description of any models which are used and associated software packages which support the DSS analytical capabilities.
- <u>Interface (Dialog)</u> - The interface is the subsystem through which the user commands the CMDSS and through which information is presented to the user.
- <u>Knowledge</u> - What, if any knowledge bases are used in the DSS.
- <u>Hardware</u> - Major hardware options are networks, mainframes, minicomputers, personal computers, or any combination of the above.

- Software - Software consists of programs and routines that support the operation of the computer system.

The four CMDSS being evaluated in addition to the TEDSS are:

- ERMS - The Federal Emergency Management Agency's Emergency Resources Management System.
- META-FIRE - The USDA Forest Service's Executive Information System to Support Wildfire Declaration.
- Tactical Combat Operation (TCO) - The United State Marine Corps' Automated, Real Time Display/Information Processing System to Support Operations and Intelligence Functions.
- Computer Aided Dispatch (CAD) - The LifeFleet's CAD, Pinellas County, Florida's Paramedic Emergency Response Service.

B. EMERGENCY RESOURCES MANAGEMENT SYSTEM (ERMS)

1. Overview Description

ERMS is the Federal Emergency Management Agency DSS used to manage local, regional and national disasters. The ERMS is an automated, menu-driven system that does not require specialized computer expertise. (ERMS, 1990).

The main menu consists of the following:

- View Current Resource
- Resource Selection
- Weapon Effects
- File Management
- Data Registration
- Quit

The first functional menu option is View Current Resource. The resources which can be viewed are vital assets available to the federal government such as agriculture, communications, energy-power, finance systems, government continuity, health, manufacturing, population and others. This option allow the user to select a resource, a geographic area, and a weapon effects setting. The user moves the up and down arrow key on the keyboard to highlight View Current Resource and then presses the <ENTER> key to confirm the selection. Upon selecting View Current Resource from the ERMS Main Menu, the list of current queries is displayed. The list of queries contains the default query (Select All Data) and existing user-defined queries. An option to create user-defined queries is also provided if the user presses the <TAB> key.

The second menu option is Resource Selection. Resource selection allows the user the capability to pick a resource for use within ERMS. This

function provides a listing of all resource names available, and prompts the user to choose a resource.

The third menu option is Geographic Selection which provides the user with the capability to choose a specific geographic area from a list that includes the nation, regions and states.

The fourth menu option is Weapon Effects which provides the user with the capability to view and update nuclear blast, casualty, and fallout maps and the capability to view data with Weapon Effects ON or OFF. Additionally, this option provide the user with the capability to view estimated risk data associated with specific geographic locations.

The fifth menu option is File Management which provides the user capabilities to manage the resource and damage data base files used by ERMS:

- Display of installed databases or loaded data files.
- Modification of current resource data.
- Modification of current resource names.
- Archive of resource databases.
- Archive of damage databases.
- Download of damage database from the VAX.
- Restoration of databases from diskette.
- Removal of resource databases (resource name intact).
- Deletion of resource databases (including resource names).

- Display of available disk space.

The sixth menu option is Data Registration which provide the user with the capability to prepare data for use by ERMS. The Data Load module which supports the Data Registration process, provides the following functionality:

- Imports both dBase structure databases and ASCII flat files.
- Converts an ASCII flat file into a dBase structured database.
- Creates data and data fields required by ERMS that are not provided by the user's database.
- Creates threshold queries from either the Threshold Category Code or the Datagroup type selection.
- Registers a properly formatted dBase file into ERMS.

The last menu option is Quit which provides the user with the capability to exit ERMS.

2. Data

There are two acceptable formats. Any data file to be registered by Data Load must be either a dBase structured file or an ASCII flat file. A dBase structured file should have a file name extension of "DBF". An ASCII flat file must have fixed length fields that are not separated by delimiters (i.e., spaces, commas, etc.). An ASCII flat file must have fixed length records, with each record delimited by carriage return/line feed.

3. Models

ERMS models are designed to run from the main menu functions. The model base appears to be a strategic platform but the exact types of models used in ERMS could not be determined.

4. Knowledge

ERMS does not employ knowledge bases.

5. Interface (Dialog)

ERMS employs a regular keyboard and function keys. The display or presentation language is plain English which the user views at the terminal. A VGA display screen provides color graphics of maps which range from local, regional and state levels. These maps are generated from software purchased from Titan Corporation Graphics. The knowledge which the user must have in order to use the system is contained in the ERMS user's handbook.

6. Hardware

The ERMS hardware configuration consists of a DATA-SEC 386 IBM compatible stand-alone PC with three 80 Mbyte removable disk drives, a line printer and a console terminal.

7. Software

The ERMS software suite includes products for Titan Corporation Graphics and uses DOS version 3.3.

The ERMS appears to satisfy some of the established CMDSS requirements. The ERMS meets the Rapid Response requirement through its 386 computer. Response to main menu functions is performed in a few seconds which is adequate response time to react to unfolding emergencies. Through regular use, the ERMS has demonstrated its reliability and its capability to function with desired accuracy; thus meeting the Reliability requirement of a CMDSS. The ERMS does not meet the Ease Of Use requirement of a CMDSS. It has a rather bothersome menu-driven keyboard interface which appears to be difficult to manage without extensive user training. The ERMS does not meet the Critical Activities Prompt requirement of CMDSS. The ERMS protects the user from information overload through its hierarchical menu configuration which provides only the information requested by the menu function; thus meeting the Information OverLoad requirement of a CMDSS. The Knowledge requirement of a CMDSS is not met by ERMS. The Sophisticated Graphics requirement of a CMDSS is met by ERMS. The system employs a graphics package produced by Titan Graphic Corporation to provide maps of regional, state and local areas of concern. The ERMS is a response CMDSS in that it reacts only to users' requests. The ERMS is considered a real-time system because the user can retrieve information in a matter of seconds; therefore, the Real-time System requirement of a CMDSS is met. The ERMS is designed to support decision making during threat conditions including nuclear detonations.

The ERMS users have confirmed that the system meets its mission requirement. This DSS was specifically designed for use by FEMA to perform the functions listed on its main menu. Although the ERMS does not fulfill all of the requirements of a CMDSS, it nevertheless qualifies as a bona fide CMDSS. The ERMS uses conventional technology which is not well suited for transfer into a revision of the TEDSS. The ERMS' graphics are better than the TEDSS' graphics in resolution and clarity; however, there are more sophisticated graphics packages on the market today.

C. META-FIRE

1. Overview Description

META-FIRE is an executive information system to support wildfire emergency declaration decisions. This system was developed by USDA Forest Service of East Lansing, Michigan. META-FIRE was developed to aid top decision makers at FEMA headquarters to accelerate emergency declaration decisions. The purpose of META-FIRE is to monitor and forecast weather and fire activity across the country and provide reliable, consistent and unbiased information to all three principals (i.e., FEMA's technical advisor, Disaster Program Manager, and Governor's office) in the declaration process. (Simard and Eenigenburg, 1990, pp. 186-187)

Application for emergency funding for an ongoing fire is a complex process because of the many elements involved which include contacting the

technical adviser, submitting reports, reviewing for compliance with eligibility criteria, and awaiting notification of the preliminary decision. This complexity often slows emergency decisions which are potentially critical to containing an outbreak before it becomes a disaster. (Simard and Eenigenburg, 1990, p. 187)

Weather data is automatically accessed from multiple national weather data networks. Large fire data is manually entered. A database management subsystem uses custom and commercial software packages to process and archive daily weather files. The decision support subsystem calculates the daily probability of a large wild land fire for every climate division in the country. The system produces one page executive reports oriented to management by exception. On-site graphic software converts the reports into national and regional maps. The 99 percent reliable PC-based system predicted 75 percent of all large fires during 29 months of testing. (Simard and Eenigenburg, 1990, p. 53)

2. Data

The data base is managed with a combination of commercial and custom software. As of 1989, the data base had accumulated 8,000 operational, backup, and archive files requiring 80 megabytes of storage. The data base is divided into three parts: operations, archives, and management (Simard and Eenigenburg, 1990, p. 61).

3. Models

The technical heart of the system is the decision support models which transform weather information into the probability of large wild-land fires. The models include a severity index, an expert system, and large-fire probability. The severity index includes six components: (Simard and Eenigenburg, 1990, p. 62)

- Upper air (air mass stability and moisture).
- Spread (instantaneous rate of spread).
- Short-term (two-day moisture balance).
- Mid-term (weekly moisture balance).
- Long-term (monthly moisture balance).
- Season (state of the vegetation and winter).

The index also includes four attributes that are part of the underlying structure: (Simard and Eenigenburg, 1990, p. 62)

- A base map (National Weather Service climate divisions).
- Four fuel classes (brush, conifer, deciduous, and grass).
- Climatic normals (average fire danger, climate class, and season codes).
- Time and space coordinates (location, elevation, time zone, and region).

The expert system model attempts to capture and quantify non-weather information that affects the probability of a large fire and use it to

adjust the severity index. This model includes four components: profile analysis, spatial analysis, time series analysis, and fire load. This model increases the percentage of correctly identified large-fire conditions or reduces the percentage of days above the advisory threshold. Additionally, this model reduces large-fire probabilities at low index levels and increases large-fire probabilities at high index levels. (Simard and Eenigenburg, 1990, p. 195)

4. Knowledge

META-FIRE incorporates knowledge in the CMDSS through the expert system which attempts to capture and quantify non-weather information that affects the probability of a large fire. The expert system uses this information to adjust the severity index.

5. Interface (Dialog)

META-FIRE is a menu-driven system. The links which interface the META-FIRE information system to the input network includes three modules: communications, error processing, and data extraction. The communication module links the system processor and the data base to the outside world. Communication is via telephone and three commercial electronic mail networks. Data extraction condenses a large amount of raw weather data by approximately 90 percent. The interface which the user sees is the keyboard. (Simard and Eenigenburg, 1990, p. 60-61)

6. Hardware

META-FIRE hardware consists of one 386/16 processor with a 80mb hard drive or a 386/20 backup. Both processors have math coprocessors. It operates in a PC configuration only with no mainframe capability. Its peripherals include paint-jet color printer, 6-pen plotter, and Polaroid palette. Input/output peripherals include floppy drives, modems, a scanner, and a FAX board.

7. Software

Commercial and custom software are used in this CMDSS. Commercial packages were used to minimize development time. These include a file manager, a spread sheet, a word processor and line editor, a FORTRAN compiler and extended library, three graphics and presentation packages, a mapping and map editing package, and a statistical analysis package. Independent software packages were used because no "full-featured" system did everything that was needed. (Simard and Eenigenburg, 1990, p. 60-61)

META-FIRE meets the Rapid Response requirement of a CMDSS through its 386/16 processor technology. META-FIRE satisfies the Reliability requirement of a CMDSS in that META-FIRE has functioned with 99 percent reliability and has predicted 75 percent of all large fires during a 29 month testing period. The measure of this system's reliability is determined by information availability; information availability must approach 100%. The Ease Of Use CMDSS requirement is met through the system's menu-driven

keyboard interface. This system requires user training in commercial E-Mail networks. META-FIRE does not meet the Critical Activities Prompt requirement of a CMDSS. The Information OverLoad requirement of a CMDSS is being met by this system. Because some agencies report daily and others irregularly, information overload is not a problem in META-FIRE. This system does meet the Knowledge requirement of a CMDSS. It has an expert system model which takes care of this requirement. META-FIRE meets the Sophisticated Graphics CMDSS requirement using METAMAP, a software package which reformats daily severity reports and executes a commercial mapping package. This allows the manager to produce on site national and regional severity maps. META-FIRE is considered a Responsive System. It is a near real-time system which meets the Real-Time CMDSS requirement of timely response to conditions which threaten cherished social values.

META-FIRE also satisfies the bulk of crisis requirements and qualifies as a CMDSS. The technology is a patchwork of different software and databases and relies heavily upon integration of many different hardware and software environments.

D. TACTICAL COMBAT OPERATIONS (TCO)

TCO is being developed by the United States Marine Corps to provide an automated, real-time display/information processing system to support staff operations and intelligence functions. In speaking with TCO's development

project officer, we found that TCO is in milestone 0 of its life-cycle management. Initial testing to determine whether or not to proceed to the Concepts Development Phase is in progress. The system will be located at Combat Operations Centers (COC) and Tactical Air Command Centers (TACC) and will provide a focal point where a commander can obtain operational information and disseminate command decisions. The equipment suites have yet to be determined for TCO. Recently the Marine Corps has established a test bed using commercial hardware and software to determine specific requirements and functions for planning and execution of operations. The TCO test bed is being designed to support the following functions: (MCDEC, 1986, pp. 3-18, 3-19)

- Message drafting and editing
- User defined message specifications
- User defined display symbol specifications
- Automatic store and forward of message traffic
- Automatic routing, notification, and storage of inter and intra modules message traffic
- Automatic prioritization of message by user defined categories
- Automatic notification and printing of priority message
- Multiple addressing message
- Automatic protocol and transmission medium conversion for specific protocol and links

- Error detection and automatic retransmission
- Net control-maintenance of primary and secondary network topologies
- Automatic duplication of data base information
- storage of unit status information and messages
- Unit information and message retrieval via query language or pre-defined queries
- Display of maps and situation overlays
- Retrieval of unit information via selection of unit form screen display
- User definable selection of map size, type and number of units to be displayed
- Automatic preparation of automated briefing via large screen display or monitor
- Off line local processing and programming capability
- Automatic monitoring and reporting of system status
- System diagnostic routines
- Capability to produce hard copy of message, reports, other text and graphics

This system has the potential to satisfy all established CMDSS requirements and can use much of the "state of the art" technology which is currently available on the market. If it is developed to meet its functional requirements, TCO could surpass the criteria establish in this thesis and be regarded as a prime example for future CMDSS.

Since TCO is a tactical CMDSS, the requirement of Rapid Response will be critical in TCO's automatic store and forward of message traffic. Ease Of Use require will be mandatory because tactical systems such as TCO are operated by users who constantly rotate in and out of the organization. This requires user training for optimum use of the system. A Critical Activity Prompt requirement should be deeply embedded throughout the system's design to warn the user of impending danger and necessary responsive action. The Information Overload requirement should be carefully designed into the system to filter data down to critical elements of essential information. Knowledge requirement could be built into the system to help the decision makers and possibly replace key players who are no longer available for participation. The Sophisticated Graphics requirement should facilitate the preparation of automated briefings via large screen displays or monitors. TCO designers should strive toward making the system both responsive and directive to support the diverse scenarios in which TCO may be involved. The Real-Time System requirement of a CMDSS is necessary to support the directive and responsive nature of the TCO system.

E. COMPUTER-AIDED DISPATCH (CAD)

1. Overview Description

CAD is a highly sophisticated computer-aided dispatch system developed by EAI Systems, Incorporated headquarter at Clearwater, Florida.

CAD which incorporates digital mapping technology from Etak, Incorporated of Menlo Park, California, has improved the Pinellas County's emergency response time and saved lives.

Pinellas County requires an emergency unit to be at the scene of an emergency within ten minutes of receiving a call; CAD is the system which is helping to meet that requirement. In the emergency response business, a Paramedic knows that a minute saved can translate to lives saved.

To expedite response time, the company uses historical data compiled from the system to predict high probability of accident areas and to position vehicles within those areas. The CAD CMDSS allows a dispatcher to know the precise location and status of each response unit by glancing at a wall-sized, color-coded display of a county map. A blue vehicle icon means the unit is available, yellow means enroute, red shows the unit at the scene and green means transporting to the hospital.

The wall-size display is continually updated with new information transmitted from emergency vehicles equipped with Etak Navigator and map display systems. Etak Navigator is an on board digital map that graphically displays a dynamic street map showing the vehicle's location and destination. The Navigator determines the vehicles's current position through sensors attached to the wheels and a directional device electronically linked to an on-board digital map. Every tenth of a mile, or five minutes, whichever comes first the, Navigator automatically transmits its coordinate data to the main system

at headquarters through an on-board modem and radio transmission. Because the dispatcher can see the precise location of the entire emergency fleet at once, and the precise location of the emergency, he or she can select the closest vehicle and notify it.

2. Data

CAD consists of a spatial database management system. The spatial information system combines precise graphics with a relational database. Navigator can redraw a screen map with new coordinate information in five seconds. The high speed redrawing features is possible because Navigator uses 1/10 the space of conventional map formats and can be accessed one hundred times faster. Conventional systems store geographical data in ASCII format in alphabetical order which requires a system to search sequentially to locate data. The Etak Map system is organized as a hierarchy of geographical elements which can be located quickly.

3. Models

EAI Systems Inc. generated models to produce this geographical information system (GIS). This is basically a visual model. Its power is in how it presents information rather than how it transforms data via models.

4. Knowledge

CAD does not have a knowledge-based capability. The closest it comes to this feature is to allow the user to access historical data compiled

from the system to predict high probability areas in which to position emergency vehicles.

5. Interface (Dialog)

CAD uses a keyboard for user interface with the system. Its graphics become a reporting mechanism that allows the user to visualize what resources are available and how best to allocate them to respond to an emergency situation.

6. Hardware

CAD is composed of a McDonell Douglas platform with minicomputer containing a Pick operating system. It has workstations and dumb terminals. In addition, it consist of 386 Compaq with VGA monitors.

7. Software

The CAD software is provide by EAI System Inc. via various subcontractors. The exact suite could not be determined because of proprietary restrictions.

CAD meets the Rapid Response requirement of a CMDSS in that it not only can display the location of the entire fleet of emergency vehicles, it can automatically dispatch the nearest vehicle. CAD effectively meets the Reliability requirement of a CMDSS by designing redundancy into the system. By placing a display screen in the emergency vehicle which shows the driver the vehicle destination and a map of the streets between his location and the

emergency site, a reliable and accurate guide to the emergency destination is possible. The Ease Of Use requirement of a CMDSS is met through the initial use of a keyboard which triggers the digital mapping technology displays that allows emergency personnel to perform their tasks more effectively. The Critical Activities Prompt requirement is at the heart of this system in the form of the graphical display and the immediate depiction of an emergency. The Knowledge requirement of a CMDSS is not met in this system. CAD does have the capability to access historical data compiled from the system to predict high probability areas in which to position emergency vehicles. The Sophisticated Graphics requirement of a CMDSS are more than adequately met with the mapping technology supplied by Etak Inc. The majority of the decisions are made using map displayed information. CAD meets the requirement of being a Responsive system because it respond to users request; on the other hand, it is also a directive system because it sensors allow the system to react without being requested to do so. CAD meets the Real-Time require of responding in a timely manner. Electronic sensors contribute to CAD's real-time nature.

CAD is clearly a CMDSS because it deals with conditions which if not handled in a timely manner could result in the deaths of one or more individuals. CAD is an excellent system which uses GIS technology and sophisticated sensors to perform its mission.

F. TELECOMMUNICATIONS EMERGENCY DECISION SUPPORT SYSTEM (TEDSS)

1. Overview Description

TEDSS is a management tool for NCS. The NCS was created as a result of President John Kennedy and his advisors grappling with the nuclear threat posed by the Cuban Missile crisis. Shortfalls in emergency communications slowed efforts to deal effectively with the situation. After the Cuban Missile crisis, the National Security Council sought solutions to these communications problems.

In 1963 the National Security Council created the NCS to provide necessary communications for the federal government under all conditions ranging from normal situations to national emergencies, including war (Meyer and Morris, 1988, p. 33). The types of situation for which NCS is responsible include disasters, national mobilization, intelligence activities, diplomacy, continuity of government, conventional war, protracted nuclear war and postwar recovery (Booz-Allen, 1988, p. 3-7). Presently, NCS consists of 23 governmental agencies and commercial companies which work together to provide national security emergency preparedness (NSEP) telecommunications.

The primary mission of TEDSS is to provide computerized telecommunications management assistance in the following areas: (Booz-Allen, 1988, pp. 2-3, 2-4)

- Monitoring the state of the nation's telecommunications network.
- Assessing the damage to network, facilities and communications personnel resulting from a natural disaster of national emergency.
- Tracking and processing telecommunications restoration and priorities in accordance with the national policy guidelines.
- Tracking telecommunications services requests made by claimant agencies.
- Coordinating with the National Telecommunications management System through such actions as issuing telecommunications instructions and determining emergency points of contacts.

a. Evolution of TEDSS

The need for TEDSS was identified in 1982 by federal strategic and tactical planners during a national level exercise. Standard operating procedures, plans, controls, maps, coordinates and other resources were analyzed to determine which were appropriate for automation. A prototype was developed and TEDSS was born.

The initial version of TEDSS was called the Emergency Preparedness Management Information System (EPMIS), and consisted of an IBM 4331 and RAMIS II relational data base management system (Booz-Allen, 1988, p. 2-4). EPMIS was developed using the system prototype method. The systems prototype method involves the user more directly in the design phase than does the system development life cycle (SDLC) or structured analysis method. In the case of EPMIS, operational personnel from the office of the

manager, NCS (OMNCS) were heavily involved in the analysis and design of EPMIS.

EPMIS development started in March of 1983 and consisted of six phases including the functional system description. A prototype of EPMIS was designed and implemented; and a short time later a portable unit called FAMIS was developed.

FAMIS was similar to EPMIS with reduced capability. It was designed to demonstrate the benefits of a deployable and compact system. FAMIS' size made it flexible and easy to relocate. Response time was better than that of its counterpart (EPMIS). A decision was made to combine the best attributes of FAMIS and EPMIS to produce a single system meeting the established requirements.

Both EPMIS and FAMIS were tested during national level exercises in 1984. As a result of the exercises the concept of "automated telecommunications management support" was validated. In addition to validation, the operational and feasibility test for the prototype system was accomplished. (OMNCS, 1986, pp. 2-2, 2-3)

A full-scale integrated EPMIS/FAMIS realized its initial operational capability during 1986. After 1986, the systems went through a phase of enhancements based on user interaction and input (OMNCS, 1986, p. 2-6). The system reached its full operational capability by 1990; and in 1991

the EPMIS name was changed to TEDSS to better represent the characteristics and design of the system.

b. National Level Component

The national level component of the TEDSS in Arlington, Virginia supports the NCS manager's responsibility for marshaling national telecommunications resources during an emergency. The national-level component of TEDSS provides guidance and leadership as well as information required to support a national response to an emergency. It provides a central focus which regional managers can access for guidance in prioritizing competing requests for telecommunications services. The national-level component is involved only when a solution cannot be reached at subordinate regional components.

Through a central telecommunications resources database, emergency management data is provided for both the national and the regional level components. The national-level database is the main store for the dissemination and collection of emergency data to and from the TEDSS database. Copies of the database exist within each of six regional-level components to enhance flexibility, reliability, and survivability of the information. In addition, the regionally deployed TEDSS components are updated in the same manner as the regional level components. (Booz-Allen, 1988, p. 4-3)

c. Hardware

At the national-level, TEDSS consist of personal computers (PC) connected to a Digital Equipment Corporation (DEC) MicroVax II minicomputer which contains the centralized national telecommunications data base (CNTDB) in disk storage manipulated by the INGRES database management system. The MicroVax II uses the VAX/VMS operating system. Terminals, a magnetic tape drive, disk drives, and a line printer are directly connected to the MicroVax II. (See Figure 3) (OMNCS, 1986, p. 6-6)

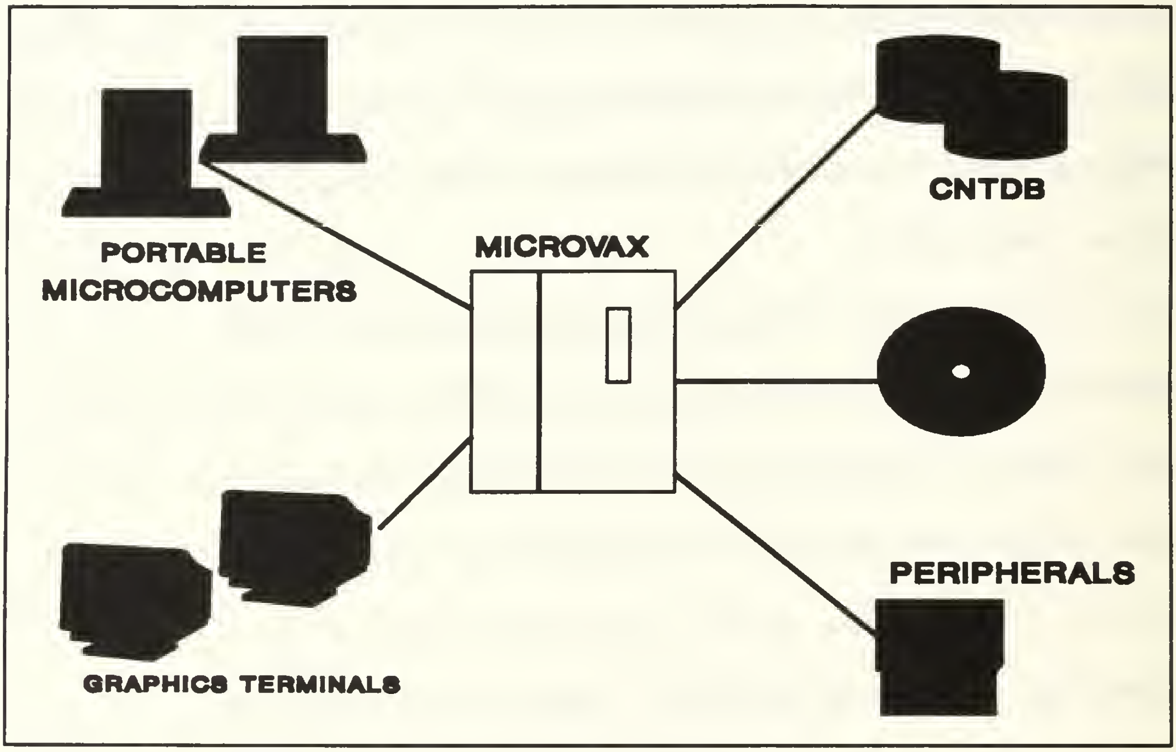

Figure 3. The National Level Component

The TEDSS network is configured across six federal regions. Each federal region is designated as a regional coordinating center and is configured to assume the position of national coordinating center if necessary. The six regional coordinating centers are located in Bothell, Washington, Denver, Colorado, Denton, Texas, Thomasville, Georgia, Battle Creek, Michigan, and Maynard, Massachusetts. The computers communicate over a DECNET network utilizing STU-III secure communications devices. Network phone and mail facilities are available for all nodes. The national database can be updated by each of the regional components and TEDSS data can be shared among all sites. (OMNCS, 1986, p. 6-9)

The TEDSS minicomputer configuration consists of a Tempest DEC MicroVax II with the following characteristics: (Booz-Allen, 1988, p. 6-9)

- 16 Mbytes of memory
- Three 75 Mbyte removable disk drives
- VT 220 console terminal
- TK50 console terminal
- Line printer
- 16-line synchronous multiplexer
- STU-III secure communications equipment

The TEDSS portable version configuration consists of a Compaq 386 with the following computer features: (Booz-Allen, 1988, p. 6-9)

- 4 Mbyte of memory
- 100 Mbyte hard disk drive
- 1.2 Mbyte floppy disk drive
- VGA graphics capability
- Color monitor (720x400) resolution
- 1 parallel and 1 serial port
- RGB interface
- Enhanced keyboard (12 function key)

d. *TEDSS System Operation*

TEDSS operates in two configurations: A flyaway portable configuration which runs on a Compaq 386 system, and an in house version which runs on a Microvax II system. Both configurations use the Unix operating system. Access to TEDSS is controlled through the use of a standard log on and password. The user interface with TEDSS is via menu-driven software. TEDSS main menu displays the following functions: (Browne, 1991, p. 7)

- Telecommunications Emergency Activation Documents
- Personnel Management
- Resource Management
- Damage Assessment
- Requirements Management (claims)

- Message Support
- Critical Site Communications

A function is accessed simply by moving the up or down arrow keys on the key board to highlight a function and then pressing <enter> to confirm the selection. Below is a description of the menu functions as describe in (Browne, 1991, p. 8-14).

(1) Telecommunications Emergency Activation Documents. This function retrieves and displays the office of Science and Technology Policy (OSTP) Telecommunication Orders (TELORD), the NCS Telecommunications Instructions (TELINSER), and the Presidential Executive Action Document (PEAD).

Contained in these documents are predefined instructions on the roles and responsibilities of the OMNCS during a state of national emergency. It also allows the user to review and update both the overall current status of the nation's state of emergency and the current status in each of the six federal regional centers.

(2) Personnel Management. The Personnel Management function provides a list of all personnel to be contacted in the event of an emergency such as points of contact for the emergency operation center and for various telephone companies. Information can be updated or deleted as necessary.

(3) Resource Management. The Resource Management function enables the user to update and monitor national telecommunication resources. Available resources are categorized as Personnel, Network, Nodes, Links, Operations Center, Asset Centers, and Assets (general). Based on parameters specified by the user, selected telecommunication resources within an area are displayed in a standard format. Resource location can be displayed on a map of the nation by federal regions or by state. Parameters can be changed in order to adjust the display. If desired, all information on a specific resource can be retrieved and displayed or updated.

(4) Damage Assessment. TEDSS contains a damage assessment model which simulates a nuclear attack and enables the user to identify telecommunications resources that may have been damaged in an attack. By providing the location and extent of the damage to TEDSS, the status of telecommunications resources affected will be updated to either predicted impaired or predicted destroyed. Each report contains a summary of the impact of an emergency on the telecommunications resources in the affected area. The assessment capability allows the user to update, execute all of the damage information in the TEDSS database against all resources, monitor damage to locations and telecommunications resources, and review damage that has been entered into an on-line journal. Damage reports can be provided summarizing the impact on the resources by region or by state and type. If needed, a graphical representation of the damaged resources in a particular

area can also be provided. Any damage information which is no longer valid may be sent to a Damage Journal where it may be edited and mapped, or deleted.

(5) Requirements Management (Claims). The Requirements Management function allow the user to enter a request for restoration or augmentation of existing failed telecommunications services such as telephones, networks, switches, microwave, etc.

(6) Message Support. The Message Support function provides TEDSS with interactive communication between two users enabling them to send and receive information simultaneously through the phone option. Non-interactive communication allowing users to send mail to other users of the system is provided through the mail option. Upon logging in to the system, a user is notified of any mail received.

(7) Critical Site Communication. The Critical Site Communication function provides the national manager, or the regional manager acting as the national manager, the ad hoc ability to input engineered networks, and generate a new network. In addition, this function enables the manager to identify and establish communication between two critical persons or locations. It also lists on-line systems where communication has been established.

2. Data

The TEDSS currently employs the INGRES relational database management system. TEDSS contains primarily record-oriented data. There are two sets of data available in the TEDSS data base: government information and industry information. There are two types of data base which support the TEDSS. A national data base is used to collect and disperse data to the distributed data bases and to provide baseline information on telecommunications resources available in the case of an emergency. Copies are maintained at each region. Each region maintains an additional local data base for use by regional managers. Data enter at the local level can be used to update the national data base. TEDSS national data base contains the following types of data: personnel, network, nodes, links, operations centers, general assets, and asset centers.

3. Models

The existing damage assessment model is coded in Fortran. Future revisions of TEDSS could incorporate an object-oriented environment which would facilitate a graphical orientation for displaying model results.

4. Knowledge

The EPMIS at one point developed an expert system for resource allocation management called XTRAM. However, it has not been incorporated into the TEDSS. Currently the TEDSS does not employ any knowledge base.

It would be useful in future revisions of the TEDSS to consider where expert systems might be applicable. A radical approach might be to reconfigure the TEDSS in its entirety as an expert system. This would require extensive use of the TEDSS in the field, however, to determine what knowledge bases are appropriate for the various emergencies.

5. Interface (Dialog)

The user interface employed by the TEDSS is via menu-driven software. The functions mentioned above can be accessed by the menu using a regular keyboard. In addition, TEDSS uses the MapInfo program which generates the maps upon which information is presented.

6. Hardware

At the national level, TEDSS consists of personal computers connected to a Digital Equipment Corporation (DEC) MicroVax II minicomputer. Terminals, a magnetic tape drive, and a line printer are directly connected to the Microvax II. TEDSS minicomputer and portable configuration features are displayed in the Overview subsection.

7. Software

The software applications and program which TEDSS employs include both commercial and custom designed application packages. INGRES is the relational data base management system which TEDSS employs.

INGRES supports the SQL query language as well as an application development environment in which TEDSS was developed.

INGRES/STAR is a distributed data base product which enables different applications to efficiently access data across a variety of computer systems. INGRES NET coordinates the processing of an application program accessing a data base on two separate machines simultaneously (Short and Bockenek, 1989, p. 16). DECNET is a set of programs and protocols for use on DEC computers systems. It is used to link the MicroVax machines in the network. Kermit is a protocol which is designed for the transfer of files over ordinary serial communications lines. Kermit allow the TEDSS users to transfer files from PC to a MicroVax and vice versa. (Short and Bockenek, 1989, p. 17)

The TEDSS is a CMDSS which provides decision makers with decision support in most of the established threat conditions which characterize a CMDSS. It meets the requirement of Rapid Response by providing requested information in a timely manner which does allow the manager to react to unfolding emergencies. It meets the requirement of Reliability by providing accurate and dependable service. However, previous research indicates that the TEDSS documentation defining the structure and relationships within the data base is incomplete making it difficult to analyze and improve system performance (Short and Bockenek, 1989). The Ease Of Use requirement of a CMDSS is not met by the TEDSS. The TEDSS has a menu-

driven keyboard dialog which could deter some users from taking full advantage of the system, especially in times of high stress. This could be improved by adopting a graphical user interface and/or voice recognition. The Critical Activities Prompt requirement is not met in the TEDSS. The Information Overload requirement of a CMDSS is met in TEDSS through the way the system hierarchical menu structure allows access to information. This menu structure does not restrict the amount of useful information, instead it allows the user to access information when it is needed. The Knowledge requirement of a CMDSS is not met by the system. The TEDSS could benefit from the rethinking and use of XTRAM. The sophisticated Graphics required of a CMDSS is partially met. TEDSS could benefit form the newer technological advances in mapping graphics such as the CAD system employs. The TEDSS meets the requirement of a Responsive System because it reacts only to the user's request for information. The Real-Time requirement of a CMDSS is met in the system because in its current state the manager can make timely responses to emergency situations. The TEDSS should be viewed as a CMDSS which partially meets CMDSS requirements. In order to fully meet CMDSS requirements, significant technology transfer is necessary.

G. TECHNOLOGY SUMMARY

It is desirable for CMDSS to keep current with "state of the art" technology to better execute the objectives of the organization employing the

system. The technology in the systems discussed in this chapter appears to reflect the technological trends which were prevalent at the time the system was developed. Much of the technology has moved from being "state of the art" at the inception of the project to "conventional" at the present time.

The data management in the systems included relational DBMS, spatial DBMS and geographical data presentation. The GIS presence either real or planned in systems such as CAD and TCO seem to indicate a trend in CMDSS data management.

Model management in the systems is primitive. The systems employed the following models: damage assessment model, visual model, severity index model, expert system model and probability model. Most of the models are "hard-wired" into the system as opposed to using "off the shelf" modeling systems. Some thought should be given to configuring CMDSS as model management systems which support many different kinds of models concurrently.

Interfaces used by the systems appear to be basic keyboard menu-driven user-interfaces. The CAD system uses graphics as a medium which allows the user to make decisions effectively. The TEDSS uses the MapInfo program which generates the maps upon which information is presented. New technology alternatives may lead into the areas of voice recognition and graphical user interfaces. A discussion of voice recognition and graphical user interfaces is contained in Chapter IV.

Of the four systems analyzed, META-FIRE was the only system which used an expert system model. This is somewhat discouraging since expert systems and artificial intelligence are arriving as a viable technological alternative. Perhaps one obstacle in the path of accepting this technology is the need for rapid response and the relative inefficiency of expert systems.

The systems discussed in this chapter met most of the established requirements of CMDSS (Table II). None of the systems met all requirements of CMDSS except for the TCO system which is still in the conceptual stage. The implications of this for the TEDSS are: (1) The TEDSS technology is out of date to meet CMDSS requirements; (2) The TEDSS is lacking in user interface capabilities, particularly GUI and GIS; (3) The TEDSS is lacking in expert system capabilities. These deficiencies are addressed in the next chapter.

TABLE II. SUMMARY OF HOW WELL CMDSS MET ESTABLISHED REQUIREMENTS

	CMDSS				
	ERMS	META-FIRE	TCO	CAD	TEDSS
CMDSS Requirements					
Rapid Response	Y	Y	Y	Y	Y
Reliability	Y	Y	Y	Y	Y
Ease Of Use	N	Y	Y	Y	N
Critical Activities Prompt	N	N	Y	Y	N
Information Over Load	Y	Y	Y	Y	Y
Knowledge	N	Y	Y	N	N
Sophisticated Graphics	Y	Y	Y	Y	N
Responsive System	Y	Y	Y	Y	Y
Real-Time System	Y	Y	Y	Y	Y
Threat Conditions	Y	Y	Y	Y	Y

IV. THE USE OF NEW TECHNOLOGY IN TEDSS

A. INTRODUCTION

The survey conducted in the previous chapter indicates that, although the TEDSS uses fairly conventional technology, it is not really that far out of step with other CMDSS. Nevertheless, it is a far cry from the "state of the art" technology so effectively employed in the CAD system and envisioned in the TCO system. The TEDSS fail to meet the requirements of a CMDSS in three critical areas: ease of use, sophisticated graphics, and knowledge. This chapter focus on these discrepancies and discusses technological alternatives which address these discrepancies. Though many new technologies are available for possible use in the TEDSS, three will be specifically discussed to bridge the gap between the ideal CMDSS requirements in Chapter II and the actual features of systems in Chapter III: voice recognition for ease of use in the TEDSS, geographical information systems (GIS) for real-time, sophisticated graphics support of the TEDSS' telecommunications resource allocation decisions, and expert systems for increased expertise and support in decision making.

B. VOICE RECOGNITION

Decision makers often find themselves functioning under conditions of extreme stress. An effective interface to a CMDSS can aid the decision maker immeasurably during a crisis by eliminating time consuming tasks such as memorizing keyboard functions. Voice recognition can be useful in situations where users cannot afford the time to interact with a system through traditional means. Sophisticated voice recognition systems such as the DragonDictate system are now available which could significantly enhance the accessibility and utility of TEDSS.

DragonDictate is a "state of the art" speaker-dependent, discrete system which can recognize up to 30,000 words at a time and has access to an 80,000 word on-line Random house dictionary. The 30,000 words is a soft limit. When this limit is reached, and a new word is used, the word least recently used will be deleted from the vocabulary so that the system can constantly adapt to the changing vocabulary. What sets the DragonDictate system apart from other voice recognition systems is that it is speaker-adaptive. With DragonDictate, the user's speech is not required to be in memory prior to operating. The system learns and adapts to the voice of the user with each successive use. (Browne, 1991, p. 22)

The DragonDictate system consists of the speech recognition software, a word library, the speech processor board, and a head-mounted microphone which plugs into the speech processor board. The speech processor is designed

to use voice commands, keystrokes, or any combination of voice and key strokes. Any functions that require the keyboard can be handled by voice commands using the DragonDictate which would meet the CMDSS requirement of Ease Of Use. This can be especially useful while the user hands are occupied. (Browne, 1991, p. 29)

The DragonDictate system requires MS-DOS version 3.3 or higher, an 80386 based computer that is PC/AT or PS/2 compatible system, either 6 megabytes of RAM for start-up or 8 megabytes of RAM for full vocabulary access, a hard disk with a minimum of 8 megabytes of free disk space, and a high density floppy drive. Each additional user who creates a file of their voice patterns will require an additional 2.5 megabytes. (Browne, 1991, p. 29)

Earlier research by (Browne, 1991) indicates that DragonDictate is currently inoperable with TEDSS because TEDSS is not designed for interaction between the user and the operating system. Without a bridge or command channel between Unix and TEDSS, the multitasking feature which would enable TEDSS to access the DragonDictate under the VP/IX shell is inoperable. This problem is not insurmountable, especially if the TEDSS were to be converted to a DOS environment which is currently being considered; therefore, various voice recognition systems should continue to be considered for TEDSS.

C. GEOGRAPHIC INFORMATION SYSTEMS

The CMDSS requirement for the TEDSS to be a real-time system is a requirement which can best be supported by GIS. A GIS approach to the TEDSS requires map overlays on which to present relevant resource information. In order to integrate GIS into the TEDSS, an object-oriented language for implementing the system is desirable in order to take full advantage of GIS. Object-oriented technology allows users to define certain elements as objects rather than as tabular data found in relational database. This change allows the user to access and manipulate individual data objects interactively. GIS will allow the TEDSS to have access to powerful modeling tools, enabling the TEDSS to run sophisticated mapping scenarios which may be more beneficial to decision makers than the simple data retrieval which currently characterizes the system.

An example of how GIS can benefit the TEDSS can be seen by revisiting a scenario of one of the discussed systems (CAD). The Pinellas County, Florida, Sunstar Communication Center receives an urgent call from the county's 911 service: a 78-year old man had just suffered a heart attack. The call which is already identified with an address by the 911 call identification system is converted automatically to a geographical location and displayed on a wall-sided color-coded digital map. Displayed on the map are the locations heading and status of each vehicle in the entire fleet. Within seconds, the optimum vehicle is determined based on location, type and status. A dispatcher then

presses a button and a signal is transmitted to the designated emergency vehicle. The on-board map device in the emergency vehicle emits a beep and immediately displays a map of the surrounding area, indicating the vehicle's current location, the location of the emergency and the direction to that location. Information related to the incident is displayed at the bottom of the map. The driver pushes a button, relaying back to the dispatcher center that it had taken the call and is enroute. The elapsed time from the moment the call was received is 18 seconds. (James, 1991, p. 9)

TEDSS can be developed using GIS to efficiently support the manager of the NCS in a similar fashion. By using maps as the primary presentation medium instead of simple database retrievals as the TEDSS currently does, information can be interpreted more quickly. In general, the manager should be able to look at sophisticated maps with color-coded lights influenced by sensors - equipment which detects, indicates and records objects and activities by means of energy or particle emissions reflected or modified by objects (JCS-Pub. 1, 1987) - to make appropriate decisions pertaining to resource allocation.

To further meet the Ease Of Use requirement of a CMDSS, a graphical user interface (GUI) should be adopted to further facilitate the GIS. GUIs provide consistent dialog box interfaces which make systems easier to use. Instead of having the user issue commands at a prompt, he or she is presented with a "dashboard" of graphical buttons and other functions in the form of icons and objects on the display screen. The user interacts with the system

using a mouse to point-and-click; presses an icon button and the associated function is performed. Other GUI tools are more dynamic and involve things like moving an object on the screen which invokes a function; for example, a slider bar is moved to determine a value associated with a parameter of a particular program.

GUIs also afford windowing capabilities which would enhance the TEDSS operations. Vendors provide a number of GUI tools that can be used to create an application-specific, on line GIS dashboard. The TEDSS could benefit from new GUI standards such as OPEN LOOK, OSF/Motif, Windows 3.0 and Macintosh. The implementation of these standards could aid the TEDSS in achieving the ease of use CMDSS requirement.

D. EXPERT SYSTEMS

One or more expert system models may also be desirable in a revision of the TEDSS in order to meet the knowledge requirement of a CMDSS. The benefits of an expert system would be realized in the following areas: (1) increased quality by providing consistent advice and reducing errors rate in the decision making process; (2) capturing scarce expertise where there is not enough expert for a decision task; (3) increased system reliability by consistently paying attention to all details and relevant information; (4) enhanced problem solving by allowing top expert's judgement into analysis.

The TEDSS originally commissioned an Expert Telecommunications Resource Allocation Module (XTRAM) which was not integrated into the system because of hardware and software incompatibility. The intent of XTRAM was to be a functioning expert system operating in either a stand-alone mode or interfaced with EPMIS. XTRAM was intended to provide the Resource Allocation Officer with recommendations as to the desired allocation of residual telecommunications resources in response to prioritized government requirements. In addition to its ability to use knowledge in an efficient manner, the expert system was capable of providing the user with a description of the decision processes involved in the generation of any resource allocation recommendation. (Booz-Allen, 1988, p. 5-6)

Another possible expert system application is prioritizing service claims as an emergency unfolds. Rules for determining these priorities could be identified and applied to each claim to ascertain when it should be filled.

E. HARDWARE/SOFTWARE

The TEDSS currently operates two versions on platform which has incompatible operating systems. One platform, which uses Unix, resides at the National Level Component and the other, which uses DOS, at the Regional Level Component. The two operating system should be standardized on a single operating system using either Unix with Motif or Open Windows, OS/2 with Presentation Manager, or DOS with Windows 3. These operating systems

have relative strengths and weaknesses with respect to their suitability for the TEDSS. Unix is a powerful mainframe OS which can support full multiuser multitasking environments reliably and efficiently. Unix is more suited to the workstation environment than to PCs; however, it's somewhat like the relational DBMSs in that it has to be squeezed into a PC box. Unix' primary advantage is it has the power to support comfortably the graphics/windows functionality of a revision of the TEDSS as described above in Section C. Disadvantages of Unix include high overhead OS compared to DOS, complexity of installation and use, and high system administration skills that are not necessary in DOS environments. (Dolk, 1991, p. 10)

Another requirement for the portable machine should be a 486 or SparcStation equivalent laptop with an attachable VGA, or HDTV, CRT. In order to handle the heavy graphic processing envisioned in a revision of the TEDSS, significant CPU processing will be required. The laptop market is finally gaining some steam and some very powerful laptop computers are emerging. A SparcStation laptop has just recently appeared with memory up to 48 MB of RAM and the CPU power of a SUN IPC. The machine weighs 13.5 pounds. 486 Laptops are also appearing. (Dolk, 1991, p. 11)

A third requirement is to use optical disk for storing the requisite maps. The data required to build maps images of the entire United States at four levels of resolution require a significant amount of storage which will easily exceed that available on the hard disk of the portable computer. These maps

can, however, be stored and retrieved very efficiently on optical disks which will not compromise seriously the portability of the fly away unit. (Dolk, 1991, p. 11)

An object-oriented language (preferably C++) should be considered for developing the system rather than a DBMS 4GL or Case tool. Real time systems are not conducive to development by 4GLs or CASE technology. Given the heavy graphical orientation of a revision of the TEDSS, an object-oriented language is the best alternative. C++ is probably the best choice since it is gaining a large measure of acceptance in industry which is creating a critical mass of professionals who can develop applications in this language. This bodes well for future maintenance and enhancements of the TEDSS. (Dolk, 1991, p. 12)

Using "State of the art" technology can definitely improve the TEDSS' effectiveness in supporting emergency decision making. Technology now exists to meet CMDSS requirements. With respect to the TEDSS, we have shown the role that voice recognition can play in increasing ease of use, that GIS can play in the presentation of information, that GUI can play in providing a consistent, easy to use interface with windows and objects, and that an expert system can play in meeting the knowledge requirement of a CMDSS. These enhancements can improve the TEDSS' performance and keep it relevant in the 21st century.

V. CONCLUSIONS AND RECOMMENDATIONS

A. INTRODUCTION

This thesis has discussed TEDSS, the automated management tool to aid the government in the management of the nation's telecommunications resources during national emergencies. By viewing the TEDSS as a CMDSS, we have developed a framework which has led us to explore the nature of crisis and stress and their related effects on decision making. From the framework, a list of requirements of a CMDSS was developed. Four CMDSS in addition to the TEDSS were reviewed to determine how well they met these requirements. The review of these CMDSS allowed us to ascertain what technology could be transferred to a revision of the TEDSS.

B. CONCLUSIONS/RECOMMENDATIONS

From this thesis research, answers to the major research questions can be presented. Technology found in CMDSS today mirrors past and current technological trends but, in general, is not well suited for a revision of the TEDSS . It is important that "state of the art" technology be used in any revision of the TEDSS to encompass some of the latest concepts in designing CMDSS. Other technological alternatives that would enhance the TEDSS are

geographic information systems, graphical user interfaces, expert systems and voice recognition.

The primary components of a CMDSS consists of data, models, user interface (dialog), and knowledge.

1. Data

The TEDSS is currently embedded within an INGRES 4GL database environment. The primary disadvantage of this setup is that it is held to a sole source vendor. Although conventional record-oriented data and a relational DBMS will still be required in subsequent versions of the TEDSS, the DBMS should only be a tool rather than the development medium.

In a revision of the TEDSS, graphics data will be in the form of map images of states, countries, and cities. Graphics capabilities are best supplied using an object-oriented language for system development in concert with an existing graphical user interface. Consideration should be given to optical storage for the retrieval and storage of graphics images such as maps.

2. Models

Model management includes software packages such as statistical, management science or other quantitative models that provide the system's analytical capabilities. TEDSS existing damage assessment model is coded in Fortran. A technological alternative for TEDSS is to implement any revision of the system in an object-oriented environment. Additional damage

assessment models should be reviewed for possible addition to the TEDSS. Consideration should be given to "visual models" which a GIS offers.

3. Interface (Dialog)

User interface (dialog) is the subsystem through which the user communicates with the DSS and through which the DSS presents information to the user. The TEDSS is currently menu-driven system. A revision of TEDSS should explore windows-based GUI. GUI provides a consistent interface to the TEDSS which meets the "Ease of Use" CMDSS requirement. The TEDSS should use a GIS approach for map overlays on which to present relevant resource information. The GIS would allow the user to dynamically describe the geographic area of interest to be assessed.

Voice recognition should be investigated as an interface for the TEDSS. This appears to be a promising alternative, especially for stressful environments such as emergency management where the cost of devoting all of one's attention to a keyboard may be high.

4. Knowledge

The TEDSS currently does not have a knowledge base capability. Subsequent revisions should consider a knowledge base for expert system applications such as telecommunications resource allocation and prioritizing claims. A look at the TEDSS's original expert system (XTRAM) should be reviewed for possible renewal.

C. AREAS FOR FURTHER RESEARCH

During the course of this research, it became increasingly apparent that a CMDSS is more than just the sum of its parts. Because of the high level perspective adopted in this survey, there were many areas which could only be covered cursorily. Many of the diversified aspects associated with a CMDSS are in themselves a thesis topic, for example, GIS database design; Voice Recognition configuration, and a more detailed framework for emergency management Crisis Decision Making.

As a result of this rude awakening, an in depth treatment could not be given to the many tantalizing subjects uncovered during this research. The following is a list of recommended topics for further research:

- Describe and evaluate plans for integrating Geographical Information Systems with TEDSS.
- Develop and validate rule-bases for relevant expert systems.
- Integrate voice recognition with a DOS version of the TEDSS.
- Explore other technologies such as hypertext for message management and virtual reality for emergency simulation exercises.

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